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Expanding the role of radiographers in reporting suspected lung cancer: a cost-effectiveness analysis using a decision tree model

Introduction

To assess whether an enhanced role for radiographers in reporting lung cancer chest radiographs is cost-effective.

Methods

Costs and outcomes of chest radiograph reporting by reporting radiographer or by a radiologist were compared using a decision tree model. The model followed patients from an initial chest radiographs for suspected lung cancer to the provision of cancer care in positive cases. Sensitivity and specificity of reporting for radiographers and radiologists were derived from a recent trial. Treatment costs and quality adjusted life expectancy were estimated over five years for those diagnosed. Deterministic and probabilistic sensitivity analyses were used to test the robustness of inference to parameter uncertainty.

Results

For 1,000 simulated patients, radiographer reporting decreased detection costs by £8,500 and detected 10.3 more cases at initial presentation. After including treatment costs and outcomes, radiographer reporting remained cheaper than radiologist reporting and resulted in 1.4 additional QALYs per 1,000 screened patients. Probabilistic analysis indicated a 98% likelihood that radiographer reporting is cheaper and more effective than radiologist reporting after inclusion of treatment costs and outcomes.

Conclusion

Radiographer reporting is a cost-effective alternative to radiologist reporting in lung cancer diagnosis. Further work is needed to support the adoption of radiographer’s reporting pathway in diagnosis of lung cancer suspected patients.

Word count - 2483

Keywords

Radiographer reporting; Advance practice; Cost-effectiveness; Radiography, Thoracic; Neoplasms, lung

Highlights

- Reporting of chest radiographs for lung cancer by trained reporting radiographers is cost-effective
- Findings are robust to uncertainty in estimates of the specificity and sensitivity of radiographer and radiologist reporting
- Radiographer reporting remains cost-effective for reporting times up to fivefold more than reporting times for radiologists

- Reporting radiographers can increase diagnostic capacity within the lung cancer pathway

Introduction

Imaging has seen sustained growth in activity, driven by an ageing population, new and emerging technologies and a drive to improve patient experience and outcomes.[1,2] Diagnostic capacity is frequently identified as a barrier to improved patient outcomes,[3,4] due to rising demand and chronic shortages of consultant radiologists in the United Kingdom,[5] for all diagnoses but especially cancer.[3] Maximising the contribution of all members of the diagnostic team is central to improving capacity, efficiency and the patient experience. It also aligns with national principles outlined by Health Education England in supporting the development of Advanced Clinical Practice delivered by experienced registered healthcare practitioners.[6] The reporting of imaging examinations by appropriately trained radiographers has been advocated for some time.[7-9] The joint position of the Royal College of Radiologists (RCR) and Society and College of Radiographers (SCOR) is that any radiographer undertaking clinical reporting must perform at a level comparable to that of a consultant radiologist.[10] There is extensive evidence that suggests this is achievable across a spectrum of modalities and anatomical regions.[7,9,11-15]

The majority of studies addressing clinical reporting by trained radiographers have focused on diagnostic accuracy. Excellent sensitivity and specificity has been reported for radiographer reporting of skeletal radiographs,[7,11,12] chest radiographs (CXR),[14,16] magnetic resonance imaging of the knee and lumbar spine,[13,17] and screening mammography.[15] Limited evidence exists on the cost effectiveness of radiographer reporting. Radiographer reporting of emergency department musculo-skeletal examinations was shown to reduce diagnostic errors and cost.[18] Work by Woznitza and colleagues suggests that integrated radiographer reporting can contribute to the delivery of effective and efficient imaging services.[19] Despite recognition of the potential for an increased role for radiographers within radiology, implementation across England has been patchy.[20]

An important area in which radiographers may contribute to streamlined patient pathways and increase diagnostic capacity is in reporting CXR for suspected lung cancer. Around seven million CXR were performed in the NHS in England in 2015-16 and the numbers are rising.[2] Current guidelines from the National Institute of Health and Care Excellence (NICE) recommend a CXR for persistent symptoms of haemoptysis, dyspnoea, chest pain, cough or weight loss with suspected lung cancer cases confirmed by computed tomography (CT) scan.[21] Historically, CXRs were only reported by consultant radiologists. Now an increasing number of trained reporting radiographers perform this role.

Early diagnosis of lung cancer is essential, and England has worse outcomes compared with many other countries.[22] Missed cases and delayed diagnosis are likely to narrow treatment options and worsen prognosis, impacting on downstream treatment costs and outcomes. There is an extensive literature comparing radiographer and radiologist reporting which indicates similar diagnostic performance.[12] However, few studies have evaluated the cost-effectiveness of radiographer reporting compared with radiologist reporting.[18,23,24] Hence, the likelihood of lower reporting costs for radiographers when compared with radiologists may not translate into a cost-effective use of health care resources. In this paper we use a decision model to assess the cost-effectiveness of reporting of CXR by trained radiographers compared with radiologists.

Methods

We compared the costs and outcomes of trained radiographer and radiologist reporting of CXR from a perspective of the National Health Service using a decision tree to model the pathway from first presentation to subsequent treatment. The model simulated a cohort of 1,000 patients in order to capture the diagnosis and treatment costs, and the outcomes of screening in terms of cases detected at first presentation and quality adjusted life expectancy over the subsequent five years. The radiologist reporting arm of the decision tree is shown in Figure 1. The structure of the radiographer reporting arm is identical to this. Patients with suspected lung cancer undergo a CXR which is reported either by the radiographer or a radiologist. Positive results are confirmed by CT scan which provides provisional staging. Treatment of confirmed cases is commenced according to disease stage. False negatives are assumed to present at an Emergency department at a later date and to receive a confirmatory diagnosis and subsequent treatment.

A trained radiographer was considered to hold training at masters level on the reporting of CXR and to work within the practice framework outlined by the RCR and SCoR.[10] Costs and quality adjusted life expectancy over five years following diagnosis according to cancer stage were estimated from the literature. We evaluated the overall diagnostic costs and the number of cases detected at first presentation with radiologist and radiographer reporting. We also estimated the cost per quality adjusted life-year (QALY) after including estimates of the cost and quality adjusted life expectancy associated with lung cancer diagnosis according to stage at diagnosis. Costs are reported in 2014/15 GBP and costs and outcomes were discounted at 3.5% following guidelines for cost-effectiveness analysis.[25] The assumptions underpinning the analysis are shown in Box 1.

Data sources

The sensitivity and specificity of CXR reporting by radiographers and radiologists were drawn from a diagnostic accuracy study that compared a cohort of consultant radiologists and reporting radiographers when interpreting a bank of adult CXR.[16] Other parameters for the model were drawn from relevant literature sources for non-small cell lung cancer as this type of cancer is present in around 90% of cases.[26] Parameter values and sources for each branch of the decision tree along with relevant unit costs are reported in Table 1. The prevalence of lung cancer amongst presenting patients was assumed to be 13%.[27] Sensitivity and specificity of CT scan was taken from Aberle et al.[28] The hourly cost of a radiographer (£53) and a radiologist (£156) were taken from a detailed costing study.[29] Costs per hour calculated by Lockwood for a reporting radiographer is based on salary, on-costs and education (postgraduate certificate for both CT head and CXR) rather than the examination/modality reported or output per hour. The £53 per hour radiographer costs is transferable to our model.[27] We assumed that reporting a CXR would take two minutes,[30] generating reporting costs of £5.20 for a radiologist and £1.77 for a radiographer in addition to the cost of the CXR.[31] The diagnosis cost for cases *re*-presenting at emergency departments was assumed to be the cost of an emergency department visit in addition to the cost of a CXR and a CT scan.

Disease stage at presentation for initial CXR was taken from data reported by Cancer Research UK (Table 2).[32] There is a paucity of data on the impact of missed diagnoses. A retrospective analysis of CXR in patients with delayed diagnosis reported a median of 155 days from missed abnormal CXR to treatment compared with 51 days from first abnormal CXR to treatment in patients correctly diagnosed.[33] This would suggest that a missed diagnosis on CXR delays diagnosis by 104 days Evidence of the impact of treatment delay on cancer stage is also limited. Byrne and co-workers report the change in stage between first abnormal imaging and CT-guided biopsy for 66 patients.[34] Over a median of 81 days, 17 patients progressed one stage, 5 progressed two stages and 1 progressed three stages. We assumed that patients receiving a false negative diagnosis would present 104 days later at an emergency department, at which point the proportion of patients progressing one or more stages would be as reported in Byrne et al. where progression indicated stage beyond IV patients were assumed to remain at stage IV.

Table 2 also summarises the outcomes of treatment and associated costs over five years applied in the model. In the absence of UK data we used SEER data to quantify survival. Survival at 6,18,30,42 and 54 months according to stage at diagnosis was estimated from published Kaplan-Meier survival curves.[35] Where stages were subdivided (i.e. stages IA and IB) a weighted average was calculated. Mid-year survival was multiplied by quality of life according to stage at diagnosis[36] to estimate QALYs accrued for that year. Results were discounted at 3.5% and summed over five years. Where diagnosis is delayed due to a false negative CXR *and* patients disease progresses by one stage patients were assumed to spend the intervening 104 days in the stage at initial presentation and accrued QALYs accordingly (i.e. 0.23 QALYs for patients with stage I disease). This QALY gain was added to the QALYs accrued after diagnosis at second presentation

Treatment costs according to stage of disease were taken from a publication by Cancer Research UK (2014) which includes the cost of retreatment after recurrence in the following five years.[37] We assumed a price year of 2012/13 based on the source of unit costs data for hospital stays and inflated costs to 2014/15 values using the Hospital & Community Health Services inflation index.[38]

Analysis

The model reported diagnosis costs, overall costs (diagnosis and treatment), cases detected at first presentation and QALYs gained for the cohort of 1,000 patients according to radiographer or radiologist reporting. Where one reporting strategy dominated the other (it delivered better outcomes at lower cost) we report this. Where one reporting strategy had better outcomes at higher cost we calculated an Incremental Cost-Effectiveness Ratio (ICER) which is the incremental cost per additional unit of outcome (case detected or QALY). The ICER is the difference in costs divided by the difference in outcome for the more effective reporting strategy compared with the less effective strategy.

The impact of parameter uncertainty in our estimates of the prevalence of lung cancer, sensitivity and specificity of radiologist and radiographer reporting, lung cancer stage distribution at initial CXR and stage progression following misdiagnosis was captured using probabilistic sensitivity analysis. We specified these parameters as random variables with Beta distributions (Dirichlet distribution for stage progression) derived from the source data. A value was sampled at random from the specified distribution for each of these parameters prior to evaluating costs and outcomes. The process was repeated 5,000 times and the mean incremental costs and outcomes determined across the 5,000 simulations (each simulation followed a cohort of 1,000 patients).

The key parameter estimates of sensitivity and specificity for radiographer and radiologist reporting were drawn from a study which was powered to demonstrate non-inferiority and it is possible that differences arose through chance. Hence, in a sensitivity analysis of cost we assumed the same sensitivity and specificity for radiographer reporting as observed for radiologist reporting. Our analysis also assumed the same reporting times for radiographers and radiologists. In threshold analysis we determine the additional reporting time for radiographers at which screening costs are equal to those for radiologists.

Results

Table 3 reports the mean results from 5000 model simulations. Radiographer reporting detects more cases at initial presentation with lower diagnosis costs than radiologist reporting in all of the 5000 model simulations. Costs are modestly lower for radiographer reporting compared with radiologist reporting after the inclusion of treatment costs and quality adjusted life expectancy is increased. Table 4 provides a breakdown of stage at diagnosis for the 13% (130 patients) of the cohort with lung cancer and the QALYs accrued by these patients and their treatment costs over the subsequent five years. Increased sensitivity in the radiographer reporting arm results in a very modest shift in stage at diagnosis. The increase in patients diagnosed at stage I, for whom prognosis is good, is primarily responsible for the modest gain in QALYs accruing to the radiographer reporting arm. The shift in stage at diagnosis also generates modestly increased treatment costs in the radiographer reporting arm, primarily because treatment costs are lowest for patient in stage IV where life expectancy is short. Hence, with respect to overall costs and QALYs radiographer reporting again dominates (delivers improved outcomes at lower cost) radiologist reporting. Across the model simulations the probability that radiographer reporting dominates radiologist reporting with respect to overall costs and QALYs is 98%.

In sensitivity analysis in which we assumed the same sensitivity and specificity for radiographer and radiologist reporting of CXR radiographers remained cheaper than radiologists in all 5,000 simulations. Threshold analysis indicated that diagnosis costs for radiographer reporting rise to the same value as that for radiologist reporting when reporting time for radiographers is increased to 11.3 minutes.

Discussion

Main findings and interpretation

Our analysis indicates that utilising trained radiographers to report CXR is cost-effective. In terms of diagnosis costs such a change is likely to save money without compromising detection rates. When we include treatment costs and outcomes radiographer reporting remains cost-effective.

Our findings are underpinned by a study which found improved sensitivity and specificity for trained radiographer reporting compared with radiologists but was powered to test non-inferiority, and the differences observed may have been a chance finding. We undertook probabilistic analysis in which we propagated the uncertainty in the specificity and sensitivity of both radiographer and radiologist reporting through the analysis. The results indicate it is highly likely that radiographer reporting is cost-effective despite uncertainty in estimates of sensitivity and specificity. Further sensitivity analysis in which we assumed the same sensitivity and specificity for trained radiographers and radiologists supports this.

Our findings support an option to expand the contribution of trained radiographers to report CXR for lung cancer. Such a policy would maximise scarce consultant radiologist capacity, concentrating their efforts on more complex imaging, multidisciplinary team meetings and interventional procedures. It might also help hospitals to meet targets for diagnosis following referral. In addition, radiographers may value the role development. For centres with an existing cohort of trained CXR reporting radiographers implementation would not require any significant changes in infrastructure or personnel. Otherwise, additional education and training, with supervision and mentoring from clinical radiologists, will be required to support radiographers in developing reporting skills.

Strengths and limitations

In this modelling exercise we draw on the best available evidence on the sensitivity and specificity of radiologist and radiographer reporting of CXR to estimate the impact on downstream treatment costs and consequences. Our analysis extends beyond traditional consideration of diagnostic performance and initial screening costs. We follow good practice guidelines for economic modelling and undertook a probabilistic sensitivity analysis to fully capture the impact of sampling variation in parameters on cost-effectiveness estimates. In addition to this we have undertaken further sensitivity analysis on the assumptions underpinning our analysis.

There are a number of limitations of this study. Firstly, our analysis is based on a model and all models are an abstraction from real life. They do, though, allow us to focus on the most salient parts of the care process. Second, our analysis made a number of assumptions, mainly due to a lack of available data (box 1). We assumed no difference in sensitivity and specificity according to disease stage. In reality, patients at an earlier stage with smaller tumours may be more difficult to diagnose. We assumed the same reporting time (2 minutes) for radiographers and radiologists, although threshold analysis suggests are results are robust to this assumption. We made some simple assumptions on survival, quality of life, and treatment costs following diagnosis. Finally, we have not considered the implementation costs of increasing the role and scope of practice of radiographers to report CXR. Future research to apply the model developed in the current study to clinical practice would address many of limitations identified and allow data to replace assumptions, for example implementation costs of implementing radiographer reporting, sensitivity of CXR interpretation, patient survival and treatment costs. Current work is underway to investigate.[39]

Comparisons with the literature

An early study of musculo-skeletal radiograph reporting in A&E found a reduction in cases re-presenting after misdiagnosis along with cost savings following introduction of trained radiographer reporting.[18] An economic evaluation alongside a RCT of radiographer led immediate reporting of musculo-skeletal radiographs also found a reduction in interpretive errors associated with immediate reporting.[23] The authors disregarded a reduction in QALYs of 0.005 associated with radiographer reporting as a statistical artefact and concluded immediate reporting reduced costs without impacting on outcomes. Brown and Desai concluded that Barium enemas were 20% cheaper when performed by radiographers compared with radiologists.[24] These findings are consistent with our analysis. However, our analysis goes further than previous studies in quantifying the cost-effectiveness of radiographer reporting rather than assuming similar effectiveness and quantifying cost savings.

Conclusions

The use of trained radiographers to report CXR is effective and cost-effective. An increased role for radiographers in diagnosis of lung cancer would release precious radiologist resource, could improve patient outcomes and may assist hospitals to meet targets on waiting times for diagnosis of lung cancer.

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Box – assumptions underpinning the analysis

- Time taken to report CXR is 2 minutes for both radiographers and radiologists
- False negatives present at A&E at a later date at which point disease may have advanced a stage (for patients at stage I to III)
- Sensitivity and specificity of radiographer reporting of CXR and radiologist reporting of both CXR and CT-scan is independent of disease stage or other patient characteristics such as age.
- QOL in the year following diagnosis (according to stage at diagnosis) is maintained in subsequent years
- There is no QOL impact arising from false positive reporting
- Findings for non-small cell lung cancer are representative for lung cancers in general

Table 1. Diagnosis costs and probabilities for chance nodes in the decision tree

Parameter	Value	Source
Chance node probabilities		
Lung cancer prevalence	0.13	Field 2014[27]
Sensitivity - Radiologist reporting CXR	69.7	Woznitza 2016[16]
Specificity - Radiologist reporting CXR	80.9	Woznitza 2016[16]
Sensitivity - Radiographer reporting CXR	78.1	Woznitza 2016[16]
Specificity - Radiographer reporting CXR	85.2	Woznitza 2016[16]
Sensitivity - Radiologist reporting CT Scan	94.4	Aberle 2013[28]
Specificity - Radiologist reporting CT Scan	72.6	Aberle 2013[28]
Costs		
Cost of CXR	£30	NHS Reference Costs 2014/15[31]
Total cost of radiologist reporting CXR	£35.20	Lockwood 2016[29]
Total cost of radiographer reporting CXR	£31.77	Lockwood 2016[29]
Cost of A&E treatment	£ 141	NHS Reference Costs 2014/15[31]

CXR – chest radiograph, CT – Computed Tomography, A&E – Accident and Emergency

Table 2. Costs and quality adjusted life-years (QALYs) for lung cancer patients following diagnosis

Cancer stage at diagnosis					
Parameter	Stage I	Stage II	Stage III	Stage IV	Source
Stage at first presentation	0.15	0.08	0.22	0.55	CRUK 2013[32]
Stage at second presentation following misdiagnosis	0.10	0.09	0.18	0.64	CRUK 2013[32] and Byrne 2014[34]
Quality of life following diagnosis	0.81	0.77	0.76	0.76	Naik 2015[36]
Total QALYs after discounting	2.95	2.11	1.28	0.52	Survival from Groome 2007[35]
Treatment costs following diagnosis	£ 16,740	£ 19,072	£ 21,408	£ 13,342	CRUK 2014[37]

CRUK – Cancer Research UK

Table 3 Base case simulation results

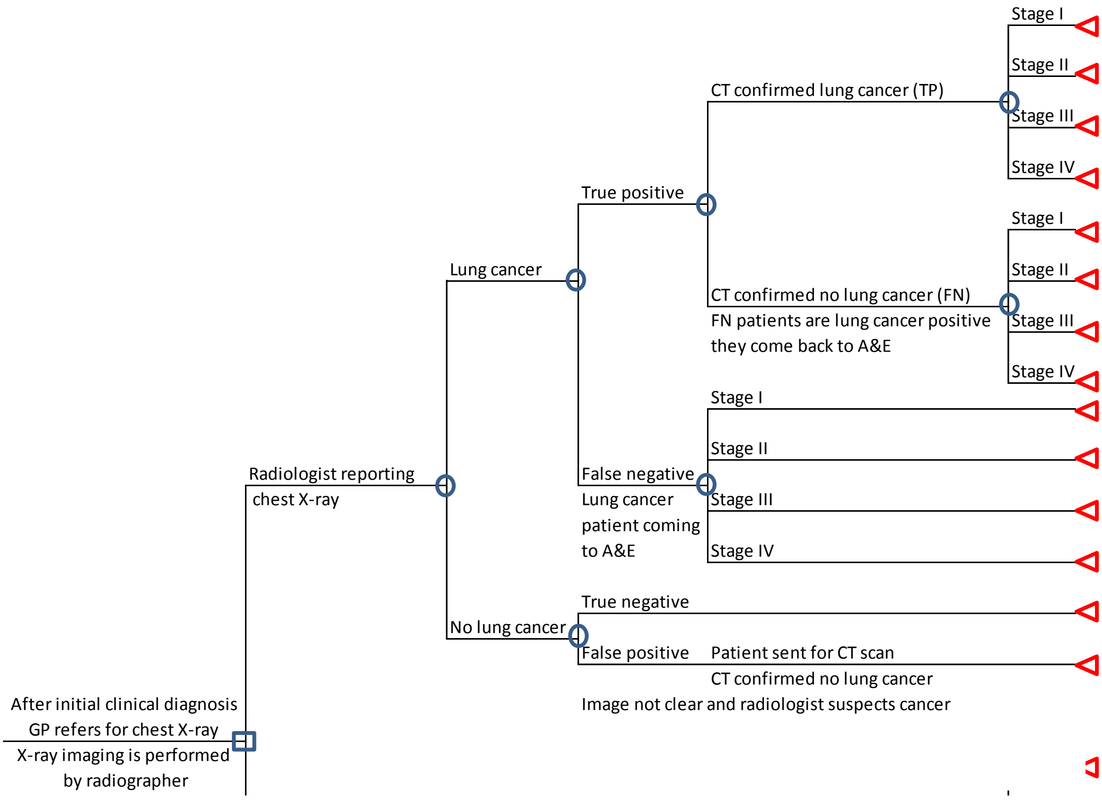
Reporting Professional	Diagnosis costs (£)	Diagnosis and treatment costs (£)	Cases detected at first presentation	QALYs accrued	ICER (cost per QALY, £)
Radiographer	60,149	2,137,983	95.87	148.74	Dominates
Radiologist	68,642	2,142,299	85.52	147.39	

QALY – quality adjusted life expectancy, ICER – Incremental Cost-Effectiveness Ratio

Table 4 Distribution of stage at diagnosis and resulting treatment costs and outcomes in Radiographer and Radiologist arms

	Stage I	Stage II	Stage III	Stage IV	All stages
Patients diagnosed – radiologist reporting	17.2	10.9	26.6	75.3	130.0
Patients diagnosed – radiographer reporting	17.7	10.8	27.1	74.4	130.0
QALYs gained – radiologist reporting	50.7	22.9	34.1	39.7	147.4
QALYs gained – radiographer reporting	52.3	22.7	34.7	39.1	148.7
Treatment costs (£) – radiologist reporting	287,526	207,476	569,712	1,005,099	2,069,813
Treatment costs (£) – radiographer reporting	296,547	205,361	579,576	993,242	2,074,725

Figure 1. Radiologist reporting arm of the decision tree.



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